Martian Timekeeping

Introduction

Timekeeping has traditionally been an integral part of astronomy and has grown quite complex along with the rest of life. A full introduction to timekeeping and calendars as they are related to astronomy is given in the Explanatory Supplement to the Astronomical Almanac. There are many time standards, including *atomic time* kept by a large array of clocks which is thought to be the most accurate standard. *Universal time*, governed by the rotation of the Earth, is what most of us think of as the true measure of time. Being closely related to the time indicated by a sundial, *ephemeris time* is governed by the orbital motion of objects in the solar system, but due to relative effects, there are many possible frames for ephemeris time.

In seeking a *martian time* standard and calendar system, we should be driven by the practical needs of those who will, in the not too distant future, be working and living in the Martian environment. It will no doubt be some time before an extremely accurate local standard is available there. Calendar constructs based on terrestrial analogy are useful since they can be easily understood by all and they may incorporate psychologically valid ideas (e.g., circadian rhythms). Consequently, the same terms may be used to refer to somewhat similar constructs in the martian and terrestrial contexts. To avoid confusion, we will adopt the practice of referring to the martian analogy of a terrestrial quantity by using the prefix areo- (from the Greek Ares for Mars). For example, the martian equivalent of a day has long been referred to as a sol (a more precise definition is given below). If Martians were to make use of an interval of 7 sols, corresponding to a terrestrial week of 7 days, we would refer to this unit of time as an areoweek.

Astronomical Facts

The martian sidereal rotation period, with respect to the fixed stars, is 24 hours, 37 minutes, 22.66 seconds or 1.026 days. Its sidereal orbital period is 686.98 days. Thus, Mars rotates 669.6 times on its axis during each orbit around the sun. The orbital and rotational motions are in the same sense; there are only 668.6 sunrises and sunsets for an observer on Mars during the course of the orbit, so the Martian analog of a year consists of 668.6 sols. Each sol, the analog of a day, is 686.98 ÷ 668.6 = 1.0275 Earth days (24 hours, 39 minutes, 35 seconds).

The eccentricity of the Martian orbit is great enough (.0934) that the planet's angular speed varies greatly over its orbit. The insolation rate (i.e. the amount of sunlight falling on Mars) also varies measurably. The planet has very pronounced seasonal changes which should be incorporated into a calendar system.

The traditional challenge of calendar making has been to take disproportionate periods and to find an approximate that allows humans to keep track of celestial events. In the terrestrial case, the lunar period is generally also a part of the calendar, in addition to the day and solar year, though the association has been largely lost in modern times. On Mars, there is no appropriate lunar period to include, but months may be retained because of the strong association of different terrestrial months with the seasons.

Astronomers measure the Martian seasons in terms of the solar longitude or L_s, a measure of the apparent motion of the sun through the sky. At the vernal equinox, L_s =0°; at summer solstice, L_s =90°; at autumnal equinox, L_s=180°; and at winter solstice, L_s =270°. The association between "months" and the seasons can be retained if each month corresponds to 30° of L_s. The analogous construct in terrestrial timekeeping is the motion of the sun through the signs of the zodiac.

Short Timescales

The division of a day into 24 hours has been very convenient for human activities. How can we most conveniently divide the 88775.25 seconds in a martian sol? , 88776 can be divided into 24 x 3699, but this period is about 0.75 seconds too long. The use of an integral number of such seconds in a sol inevitably leads to huge correction periods. Nowadays when everybody's watch is accurate to a few seconds per year, there's no way to implement this gracefully. It seems that the only feasible solution is to define the areosec to be equal to 1.0275 sec, with 60 areosec=1 areomin, and 60 areomin=1 areohour. Then the sol is made up of 24 areohours, each of which is slightly longer than our familiar hour. (Note that, astronomers already use sidereal clocks whose units are slightly shorter than the conventional ones.)

Longer Timescales

A Martian year of about 668 sols is too long a period to be practically useful for humans as the next interval larger than a sol. Therefore, it seems appropriate to retain the equivalent of months as smaller units, which can be coordinated with the seasons rather than with lunation. This introduces two problems:

- A month averaging 56 days is still quite long.
- In order to correspond to the seasonal cycle, the lengths of the months must vary significantly.

It is possible to deal with these points by incorporating an areoweek of 7 sols as a fundamental part of the calendar. We note that 191 areoweeks = 1337 sols, almost exactly 2 areoyears. This suggests a convenient calendar in which the year cycles between 95 areoweeks and 96 areoweeks in odd and even years. Given the adoption of twelve months to maintain the link to the seasons we can plan on retaining the names of the months with their familiar seasonal connotations. The lengths of areomonths, calculated to stay in synchronism with the four seasons are as follows:

Odd Year

	Areomonth	Length in Areoweeks	Note
1	January	7	
2	February	7	
3	March	8	L_s =0° at end of month.
4	April	9	
5	May	9	
6	June	10	
7	July	9	
8	August	8	The variable-length month.
9	September	8	L_s =180° at end of month.
10	October	7	
11	November	7	
12	December	6	Perihelion near 21December

Even Year

	Areomonth	Length in Areoweeks	Note
1	January	7	
2	February	7	
3	March	8	L_s =0° at end of month.
4	April	9	
5	May	9	
6	June	10	
7	July	9	
8	August	9	The extra week appears this month.
9	September	8	L_s =180° at end of month.
10	October	7	
11	November	7	
12	December	6	Perihelion near 21 Dec

With this system, there are only two possible Mars calendars for a given Mars year. All dates fall on the same day of the week in every year. This retains the symmetry of the annual cycle, which is dependent on the perihelion being near the beginning of the year.

In a manner of speaking, this proposed calendar is biased towards to residents of the Northern Hemisphere with its long, lazy summers and short, intense winters; on Mars where the northern and southern hemispheres have very different climates. The regular (and symmetric) pattern of month lengths is easily remembered. The only exception is August, the 8th month, which (in odd years) is 8 areoweeks long.

The average areoyear of 668.5 sols is only about 0.08 sols short of the average tropical year. This discrepancy requires the addition of about one areoweek in about 100 years. It only requires that one odd year follow the even year calendar per century. No recommendation as to which year this should be is made here.

Given a seven sol week, he names of the days of the week (which derive from the names of the planets) can be retained for Mars saving us all the need to memorize seven new names.

Epoch (initialization)

It remains to determine the starting point for the calendar. It has frequently been suggested that the era of human exploration (starting with the Viking Lander) be utilized. VL-1 landed in the summer ,of 1976, specifically on July 20, 1976 at L_s=97° -which is a similar midsummer time on Mars. This suggests that the Viking Landing day be observed on 20 July on Mars.

The cardinal points (solstices and equinoxes) fall closer to the target times of 1 January, 1 April, July, and 1 October if the Viking year is chosen as 0 HE rather than 1 HE. At 1976-07-20T04:44 UT it was noon at the Mars prime meridian. Therefore, we choose that time to correspond to 0000-07-20M12:00:00.

With this choice, we generate the following preliminary table for 6 April (the approximate date of the Vernal equinox):

Areoyear	**Earth Date**	**L_s** (at noon at prime meridian)
1	11/06/1977	0.86°
2	9/20/1979	358.97°
3	8/11/1981	0.67°
4	6/25/1983	358.78°
5	5/15/1985	0.48°
6	3/29/1987	358.59°
7	2/17/1989	0.30°
8	1/01/1991	358.49°
9	11/22/1992	0.27°
10	10/06/1994	358.45°
11	8/27/1996	0.20°
12	7/11/1998	358.34°
13	5/31/2000	0.10°
14	4/15/2002	358.25°
15	3/05/2004	359.99°

The corresponding summer solstice is about 4 July, the autumnal equinox 4 October, and the winter solstice 7 January. The New Year begins slightly before (by about a week) the winter solstice whereas on Earth it starts about 10 days after the solstice. Ls for 1 January ranges from about 264 to 268. The Earth date of 1 January 1 HE was 1977-05-27. This note is being written on 1998-01-15, which corresponds to 30 December 11 HE. The new Mars year will begin on 1998-01-28. Parenthetically, the first day of the year, or any month for that matter, is always Sunday. The day of the week of any day is the remainder when the date is divided by seven.